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SAP2D SYSTEM - AN OVERVIEW

Y. S. YU and N. A. TOEWS
Rock Mechanics Laboratory

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by

Y. S. Yu and N.A. TOEWS*

ABSTRACT

The *SAP2D* system, consisting of the main finite element program *SAP2D* and a number of companion programs such as *MSHGEN, SAP2DC, BNDGEN, SAPPLT* and *MRLPLT*, has been modified to run on a VAX-11/750 mini-computer.

The VAX Version of the *SAP2D* package contains a number of modifications to *MSHGEN, SAP2DC, MSHPLT, SAPPLT, MRLPLT* and *SAP2D*. To a large extent, they are all written in accordance with ASCII 77 fortran standard. However, the plotting routines are basically Calcomp software.

SAP2D is a static, linear elastic finite element program for analysis of two dimensional structures (plane and axisymmetric). Initial stresses, temperature effects, simulation of mining sequences, arbitrary distributed loading and gravity loading as well as concentrated force loading can be handled.

MSHGEN, MSHPLT and *SAP2DC* are considered as the pre-processor , while *BNDGEN* and *SAPPLT* are the post-processor; *MRLPLT* is a set of general purpose plotting routines which can be used for the *SAP2D* program as well as other 2-D finite element programs.

* Research Scientists, Mining Research Laboratories, CANMET, Energy Mines and Resources Canada, Ottawa.

VUE D'ENSEMBLE DU SYSTÈME SAP2D

par

Y. S. Yu and N. A. Toews*

RÉSUMÉ

Le système SAP2D, comprenant le programme principal d'analyse par éléments finis SAP2D et un certain nombre programmes auxiliaires tels que le MSHGEN, le SAP2DC, le BNDGEN, le SAPPLT et le MRLPLT, a été modifié pour exécution sur mini-ordinateur VAX-11/750.

Pour pouvoir effectuer cette adaptation, il a fallu apporter un certain nombre de modifications aux programme MSHGEN, SAP2DC, MSHPLT, SAPPLT, MRLPLT et SAP2D. Dans une large mesure, les modifications respectent la norme ASCII 77 relative au langage Fortran. Cependant, les routines de traçage sont essentiellement conformes au logiciel de la Calcomp.

Le SAP2D est une programme d'analyse statique, linéaire et élastique par éléments finis servant à étudier les structures en doux dimensions (plane et axisymétrique). Il peut analyser les contraintes initiales, les effets de la température, la simulation des séquences d'extraction, les charges distribuées de façon arbitraire, les charge gravimétriques et charges concentrées.

Les programmes MSHGEN, MSHPLT et SAP2DC constituent le préprocesseur, les programmes BNDGEN, et SAPPLT le postprocesseur. Le MRLPLT est un ensemble de routines polyvalentes de traçage qui peuvent s'adapter au programme SAP2D ainsi qu'à d'autres programmes d'analyse bidimensionnelle par éléments finis.

* Chercheurs scientifiques, Laboratoires de recherche minière, CANMET, Énergie, Mines et Ressources Canada, Ottawa.

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1.0 *INTRODUCTION*

SAP2D is a static two-dimensional linear elastic fininte element program. It was developed, based extensively on Wilson's SAP program [1], at Mining Research Laboratories (MRL). It has been used at MRL for a number of years. It can handle very large structures efficiently and economically. Recently, *SAP2D* system has been modified to run on MRL's VAX-11/750 mini-computer system.

Structural analysis using the finite element technique always involves massive input and output. To speed up data preparation and interpretation of the finite element results both pre-processor and post-processor are considered essential. Therefore, a number of companion programs or subprograms associated with *SAP2D* were also developed.

This report provides an overview to the *SAP2D* system, and a flow diagram is designated to show the functions of each subprogram and their relationship within the system.

These programs were originally developed and tested on a CDC Cyber 74 computer and a Calcomp plotter. In 1984/85, they were modified in accordance with ASCII 77 Fortran standard, and currently, they are running on MRL's VAX-11/750 mini-computer under VMS 4.0 operating system. The plotting devices for the pre- and post-processor associated with this conversion are limited to a Tektronix 4663 plotter and 4014 graphic display terminal. The option of using a Calcomp plotter is still available but it is not fully tested. However, all basic plotting routines used in this program are Calcomp software.

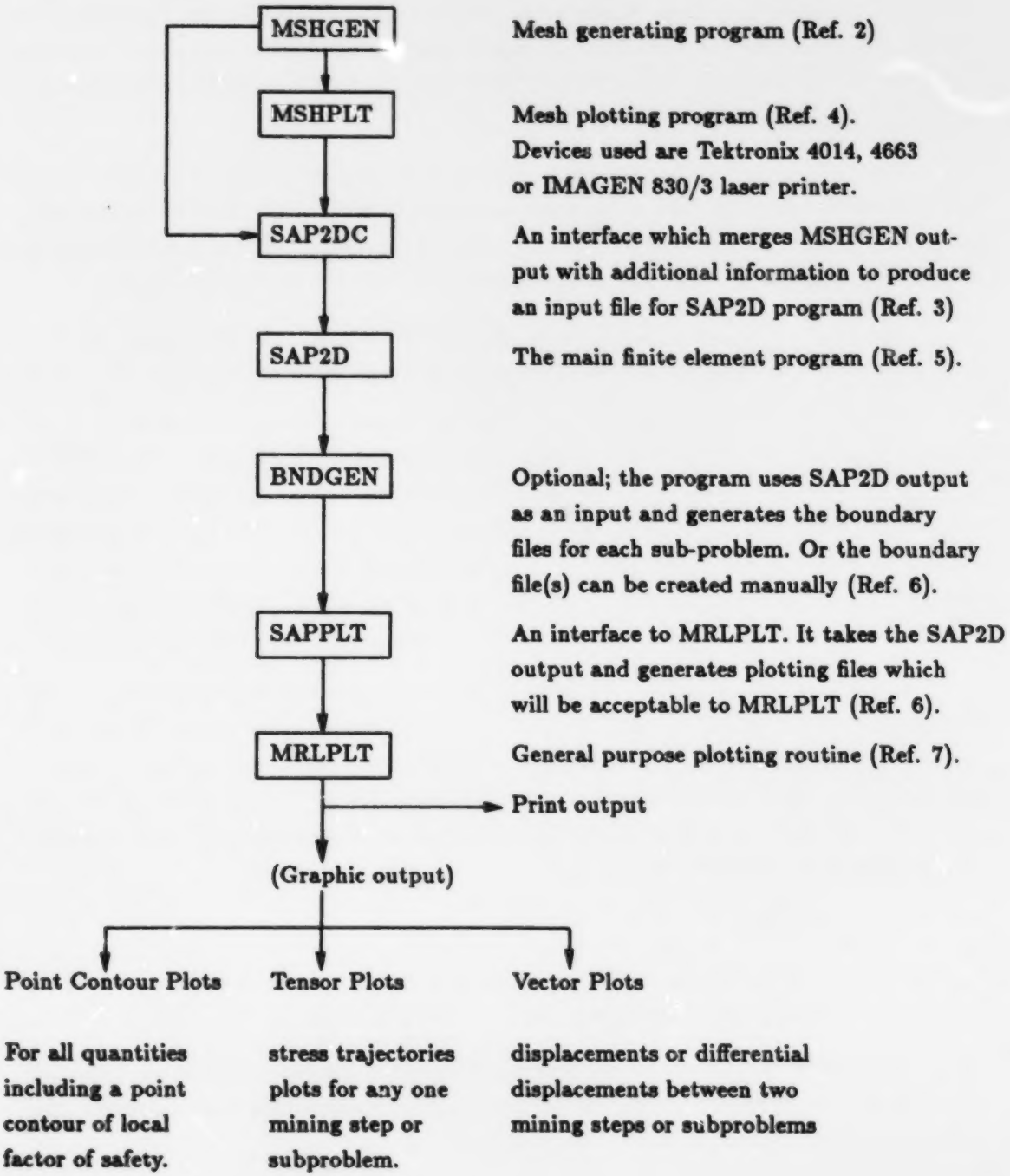
In addition, an interactive capability has been incorporated into the general purpose plotting program *MRLPLT* so that the plot can be run interactively on a Tektronix 4014 graphic display terminal for a preview, and, if required, it can be copied onto a Versatec printer/plotter. Furthermore, after a plot file is created, the plot can be produced directly on an *IMAGEN* 8/30 laser printer using Impress software. The procedure to produce report quality plot on the laser printer has been described in another report [4].

2.0 *SAP2D SYSTEM*

This section provides a flow diagram which illustrates the inter-relationship for the companion programs within the system, and is self-explannatory.

The details for each companion program are given in the documents or users manuals as referenced in the following diagram - Figure 1. It is recommended that the reader refer to those manuals if this system is to be used.

Figure 1 - SAP2D SYSTEM FLOW DIAGRAM


MSHGEN
Mesh generating program (Ref. 2)
MSHPLT
Mesh plotting program (Ref. 4).
Devices used are Tektronix 4014, 4663
or IMAGEN 830/3 laser printer.
SAP2DC
An interface which merges MSHGEN out-
put with additional information to produce
an input file for SAP2D program (Ref. 3)
SAP2D
The main finite element program (Ref. 5).
BNDGEN
Optional; the program uses SAP2D output
as an input and generates the boundary
files for each sub-problem. Or the boundary
file(s) can be created manually (Ref. 6).
SAPPLT
An interface to MRLPLT. It takes the SAP2D
output and generates plotting files which
will be acceptable to MRLPLT (Ref. 6).
MRLPLT
General purpose plotting routine (Ref. 7).
Print output
(Graphic output)
Point Contour Plots
Tensor Plots
Vector Plots
For all quantities including a point contour of local factor of safety.
stress trajectories plots for any one mining step or subproblem.
displacements or differential displacements between two mining steps or subproblems

2.1 *MSHGEN*

MSHGEN is the mesh generator that produces the major portion of finite element input data for *SAP2D*. The program *MSHGEN* closely follows the concepts and terminology introduced by Zienkiewicz and Phillips [8].

Some features of the *MSHGEN* program are:

(a) Quadrilateral elements are generated;

(b) Linearly varying pressures can be generated on element sides;

(c) Mesh grading can be achieved; and

(d) Extensive error checking of input, including a printer-plot for visual inspection is built into the program.

2.2 *SAP2DC*

MSHGEN program produces only part of the data (nodal point coordinates, element data and pressure data, etc.) required by the finite element program *SAP2D*. Other necessary information such as material properties, initial stresses and concentratrated force are absent. *SAP2DC* merges this additional information with the output file of *MSHGEN*, called *GENOUT*, to produce an input file (SAPIN) acceptable to *SAP2D*.

2.3 *MSHPLT*

Finite element analysis for mine structures or other types of geotechnical structures usually involve large and complicated geometries or configurations. The discretization and proper grading of a finite element mesh is an integral part of the stress analysis process.

The best way to check whether a generated finite element mesh is adequate or not is to plot the mesh and inspect it visually. *MSHPLT* is a mesh plotting program especially designed for use in conjunction with the mesh generating program *MSHGEN*.

2.4 *SAP2D*

SAP2D is a static, linear elastic finite element program for analysis of two-dimensional structures (plane or axisymmetric). Initial stresses, temperature effects, simulation of mining sequences (excavation and/or backfill), and arbitrary distributed loading, gravity loading as well as concentrated force loading can be handled by this program.

SAP2D is an efficiently programmed set of routines that can economically handle very large two-dimensional problems.

SAP2D was written in accordance with ASCII 77 Fortran standard, and it is currently running on a VAX-11/750 mini-computer.

2.5 *BNDGEN*

Program *BNDGEN* generates a complete boundary file for each subproblem or mining step

of a finite element model, using *SAPOUT* (output from *SAP2D* program) as an input. To execute this program, no additional information is required.

Boundary files are stored or written on the file PLTBND using format (1X,2E15.7,I5). The boundary data consists of a set of nodal coordinates (X and Y coordinates) describing one or more closed loops, in a counter clockwise or clockwise manner, corresponding to the model perimeter.

Details concerning the use of the BNDGEN program is given in Reference 6.

Alternatively, boundary files can be created manually and copied onto the logical file *PLTBND* for later use.

2.6 *SAPPLT*

SAPPLT is an interface program for the general purpose plotting routine *MRLPLT*. It converts *SAP2D* output data (stresses and displacements, etc.) into a set of input file acceptable to the plotting grogram *MRLPLT* which provides graphical representation of stresses and displacement results of any two-dimensional finite element analysis. Three types of plots can be generated from MRLPLT, and they will be described in Section 2.7.

2.7 *MRLPLT*

The function of this program is to provide graphical representation of various quantities of the finite element analysis of structures. Any number of plots can be carried out. A plot consists of a heading, a boundary and the symbolic representation of the data, called data points. This program provides three types of plots, namely:

(a) *Vectors*;

(b) *Tensors*; and

(c) *Point contours*.

The *vector* plot was designed to illustrate displacements or any similar data. The *tensor* plot produces a representation of the two principal values of second-order tensors, such as the stress trajectories of the principal stresses for a plane structures. The *point contour* can be used for any quantity dependent on two independent variables, X and Y; it assigns a symbol to each data point according the range of the data in relation to a set of contour intervals.

Each plot must have a boundary which is plotted as a set of straight lines. The boundary is determined by an ordered set of of boundary points and the type of lines to draw between them. The data points and boundary points of all plots are retained on files on storage devices such as a disc. These files can be created before or during the running this program.

The input procedure of *MRLPLT* is very flexible and can be user-defined within certain restrictions. The plot commands (card or card image input) are mainly labelled for easy recognition during the data preparation. Extensive error-checking with informative diagnostic messages are provided for most of the input.

The other features of the program are:

- Many of the plot commands input are optional.
- The ability to choose any area (rectangular) of the data points for plotting. This allow the user to magnify any area of the data to be plotted as the complete plot.
- Allows the user to have a vector or tensor plot plotted over the top of a proceeding vector or tensor plot. This provides a visual comparison of two or more sets of data.

3.0 *REFERENCES*

1. Wilson, E.L.; " SOLID SAP - A Static Analysis Program for Three Dimensional Solid Structures"; UC SESM Report 71-19; University of California, Berkeley, U.S.A.; 1972.

2. Toews, N.A., Yu, Y.S. and Wong, A.S.; " MSHGEN Documentation (VAX-11/750 Version) - A Mesh Generating Program for Finite Element Analysis of Two Dimensional Structures"; Division Report MRP/MRL 85-32 (TR); Mining Research Laboratories, CANMET, Energy, Mines and Resources Canada; Ottawa; Feburary 1985.

3. Yu, Y.S., Toews, N.A. and Wong, A.S.; "SAP2DC Documentation (VAX-11/750 Version) - An Interface Program for the Finite Element Program SAP2D"; Division Report MRP/MRL 85-34 (TR); Mining Research Laboratories, CANMET, Energy, Mines and Resources Canada; Ottawa; March, 1985.

4. Yu, Y.S.,Toews, N.A. and Wong, A.S.; " MSHPLT Documentation (VAX-11/750 Version) - A Mesh Plotting Program for Finite Element Analysis"; Division Report MRP/MRL 85-33 (TR); Mining Research Laboratories, CANMET, Energy, Mines and Resources Canada; Ottawa; Febrrary, 1985.

5. Toews, N.A., Yu, Y.S. and Wong, A.S.; "SAP2D Documentation (VAX-11/750 Version) - A 2-D Linear Elastic Finite Element Computer System"; Division Report MRP/MRL 85-35 (TR); Mining Research Laboratories, CANMET, Energy, Mines and Resources Canada; Ottawa; August, 1985.

6. Yu, Y.S., Toews, N.A., Wong, A. S. and S. Vongpaisal; "SAPPLT Documentation (VAX-11/750 Version) - An Interface Program for the General Purpose Plotting Program MRLPLT"; Division Report MRP/MRL 85-86 (TR); Mining Research Laboratories, CANMET, Energy, Mines and Resources Canada; Ottawa; August, 1985.

7. Yu, Y.S., Toews, N.A. and Morrisson, H.D.; "MRLPLT Documentation (VAX-11/750 Version) - A General Purpose Plotting Program for 2-D Finite Element Analysis"; Division Report MRP/MRL 85-87 (TR); Mining Research Laboratories, CANMET, Energy, Mines and Resources Canada; Ottawa; August, 1985.

8. Zienkiewicz, O.C. and Phillips, D.V.; "An Automatic Mesh Generation Scheme for Plane and Curved Surfaces by 'Isoparametric' Coordinates"; Int. J. for Numerical Methods in Engineering; Vol. 3, 519-528; 1971.